

REST TERMINATION AND PREDICTION MODELS FOR  
LOW CHILLING BLUEBERRIES AND NECTARINES

BY

PHYLLIS ROBINSON GILREATH

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WITH LOVING MEMORIES  
TO ALICE

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Rest Termination and Prediction Models for  
Low Chilling Blueberries and Nectarines

By

Phyllis Robinson Gilreath

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The influence of various temperature conditions on the chilling requirement of dormant plants and nonrooted budsticks of nectarine (Prunus persica (L.) Batsch var. nectarina) and rabbiteye blueberry (Vaccinium ashei Reade) was studied using computer-controlled temperature chambers. A rest prediction model was developed for low chilling nectarines and tested using orchard temperature data.

Exposure to 10°C was as effective as 7°C for floral bud-break of low chilling 'Sungold' nectarine plants. Floral bud-break of plants exposed to 14 days at 30°C in the middle of the chilling period was faster but failed to reach a level of activity comparable to that of continuous temperature treatments. Rate of bud-break increased as chilling was extended to 750 hours. The chill unit model based on these data



indicates a broader range of effective temperatures and a higher optimum chilling temperature when compared to models for higher chilling cultivars. The model predicted rest completion more accurately than other methods when applied to orchard temperature data.

Bud-break of 'Woodard' and 'Bluegem' rabbiteye blueberry occurred sooner than 'Tifblue' following chilling at constant 10° and 15° C and a diurnal regime of 10 hours at 15° C/14 hours at 7° C. Results indicate a narrower range of effective chilling temperatures for 'Tifblue'. The temperature effect was more pronounced for 'Woodard' rooted cuttings than budsticks and was not as significant for vegetative as floral bud-break. Floral bud-break of rooted cuttings subjected to 14 days at 30° C in the middle of the chilling period was faster than at continuous chilling treatments. Number of days required for bud-break was significantly reduced as chilling was increased.

Modification of plant environment was attempted by overhead sprinkling during rest on low chilling 'Sungold' and 'Sunlite' nectarines. The effect of evaporative cooling on chill unit accumulation and bloom and the influence of water on the canopy versus roots were studied. Changes in soluble carbohydrates and mineral element content were monitored as an indication of leaching. Applicability of chill unit models for predicting rest termination of sprinkled and non-sprinkled trees was determined.

Evaporative cooling advanced bloom of 'Sungold' nectarine by approximately 11 days. Soil moisture and temperature data indicate water applied to the canopy and not increased water in the root zone was responsible for the bloom advance. A rest prediction model for low chilling nectarines which accurately predicted rest termination for all nonsprinkled treatments failed to predict rest completion for sprinkled treatments, suggesting other factors are involved in addition to temperature. Soluble carbohydrate data suggest leaching of water soluble substances from the dormant tree by high rates of water application may have influenced bloom.

## INTRODUCTION

Deciduous plants cease active growth in response to decreasing daylength and temperature as they enter the dormant phase in the fall. Growth is resumed only after exposure to a specific number of hours at critical threshold temperatures. The most effective temperature for fulfilling a plant's chilling requirement has generally been assumed to be 6° to 7° C, with plants acquiring one chill unit for each hour at or below this temperature.

Temperatures fluctuate widely within a season and from year to year in areas with mild winters. Air temperatures near 28° C are not uncommon and tree cambial temperatures approaching 40° C have been reported (73). Prolonged periods of high temperatures often interrupt normal winter temperatures. Only cultivars with a low chilling requirement can be grown productively under such conditions. The number of hours at this temperature will be insufficient in some years to satisfy the rest or chilling requirement of many "adapted" cultivars. The result is delayed and erratic foliation and flowering with reduced fruit set. Conversely, rest may be completed early in unusually cold seasons, before the danger of spring frost is past, resulting in partial or complete crop loss and injury or weakening of the tree.

It has been demonstrated physiological manipulation of plant development is possible through chemical applications and cultural practices. It is first necessary to understand how the plant responds to a wide variety of environmental conditions. Incorporating this information into a mathematical model which would predict chill unit accumulation throughout rest would facilitate accurate timing of modification techniques.

Objectives of the first phase of this research were to 1) examine the response of low chilling, dormant blueberry and nectarine plants and nonrooted cuttings exposed to a wide range of temperature conditions, including constant temperatures, diurnally fluctuating temperatures and a warm interruption period; 2) determine the most effective chilling temperature for each cultivar; 3) incorporate this information into a mathematical prediction model relating temperatures to equivalent chill units; and 4) test the model using orchard temperature data.

A second aspect of this research involved modification of the plant environment by evaporative cooling in an attempt to alter the dormant period. Objectives were to 1) determine the effectiveness of evaporative cooling during the rest period for increasing chill unit accumulation of low chilling nectarines; 2) separate effects of water applied to the tree canopy versus increased water supply in the root zone; and 3) monitor changes in soluble carbohydrates and mineral elements as an indication of possible leaching.

## REVIEW OF LITERATURE

Dormancy is a general term denoting an inactive state. Deciduous fruit trees cease active growth in the fall in response to decreasing daylength and temperatures (111). The plant enters the stage of dormancy known as quiescence at this time. A quiescent plant is dormant because of environmental conditions and may be forced into growth by pruning, defoliation, irrigation, nitrogen fertilization or other cultural practices. A transition from the quiescent to resting stage usually occurs in October or November. Leaf fall normally takes place during this transition. A plant in rest cannot be forced into growth because dormancy is now under physiological control and metabolic changes must occur before rest can be completed (111).

Research has been conducted on various growth regulators and their role in the dormancy phase of peach flower and vegetative buds (10, 11, 12, 25, 44, 48, 55, 56, 54, 83, 101, 102). Results indicate seasonal fluctuations exist, with ultimate control based on an interaction between growth inhibitors and growth promoters (28, 97, 100). Growth inhibitors, notably abscisic acid (ABA), increase markedly in autumn coinciding with leaf abscission. Inhibitor levels diminish progressively throughout the dormancy period until bloom (26, 32, 36). Growth promoting compounds, such as auxins, gibberellins

and cytokinins, which counteract inhibitor effects, are also being synthesized and/or translocated, reaching peak levels coinciding with rest completion and lowest inhibitor levels (100).

Exposure to temperature below a critical level is needed during rest before a plant will respond to high temperatures and resume growth. The required duration of such exposure varies for species and cultivars within a species (15, 90, 104). After the requirements for rest have been met, the plant is able to respond to temperatures above some base level, with bud development directly correlated to temperature increases above this level and quantified as heat unit, growing-degree-hour (GDH) or growing-degree-day (GDD) accumulation (80). There are various methods of calculating and modeling GDH accumulations (3, 4, 5, 74, 80).

Numerous studies have focused upon temperature requirements for rest completion of Prunus spp. (20, 53, 69, 108) and Vaccinium spp. (31, 89, 90). The most effective chilling temperature has generally been assumed to be 6° to 7° C (49, 53, 79, 89) and one chill unit is assigned for each hour of exposure to temperatures at or below this threshold level. Erez and Lavee (49) reported 6° C was optimum for lateral peach leaf buds while 8° C was optimum for terminal buds. Others have found similar results (53, 104).

Work by Richardson et al. (79) demonstrated a mathematically derived expression relates temperature to rest completion by means of a model based on chill unit accumulation

so that an accurate prediction of when rest will or has been completed can be made. One chill unit is defined as one hour at  $6^{\circ}\text{C}$  according to this model. The value of each chill unit accumulated decreases to zero at  $0^{\circ}$  and  $15^{\circ}\text{C}$  and becomes negative above  $15^{\circ}\text{C}$  (79). This method gives a more precise prediction of rest completion than hours below a certain minimum as it takes into account the contribution of suboptimum temperatures.

Little research has been done on the effects of subfreezing temperatures on peaches or blueberries. Richardson et al. (79) did not consider temperatures below  $1^{\circ}\text{C}$  as contributing to chill unit accumulation; thus, they were given a chill unit value of zero. Lamb (59) found a constant temperature of  $0^{\circ}$  to  $7.2^{\circ}\text{C}$  most effective for raspberries, but after an initial check, continuous exposure to subfreezing temperatures ( $-3^{\circ}\text{C}$ ) broke rest as fast or faster than higher temperatures. Sparks (88) found temperatures from  $-1^{\circ}$  to  $-13^{\circ}\text{C}$  progressively hastened bud-break of pecans with only one night's exposure.

The use of  $6^{\circ}\text{C}$  as a limit below which chilling is effective has been questioned, as temperatures above  $6^{\circ}\text{C}$  will terminate dormancy (49, 53, 83). Low chilling peaches reach an acclimation base at a higher temperature than cultivars adapted to higher latitudes (17, 18). This same trend is probable for the chilling requirement, as rest predictions from bloom data on Florida peaches and nectarines correlate more closely with chill unit accumulation when  $10^{\circ}\text{C}$  is used as a base (19, 52). Weldon (110) concluded as early as 1934

the threshold temperature for chilling of peaches in California was between  $9.6^{\circ}$  and  $9.8^{\circ}$  C.

Many chilling studies have been done with constant low temperatures but the effect of diurnal variation in temperature must be considered when determining chilling temperature requirements, especially in warm climates with high daily maxima. January means in Florida are above  $10^{\circ}$  C. Maximum temperatures in scaffold limbs may exceed  $38^{\circ}$  C, with changes as fast as  $13^{\circ}$  C per hour (73). Antagonistic effects of these temperatures on chilling accumulation must be determined.

Bennet (9) found constant exposure to  $2.8^{\circ}$  C broke rest of peaches faster than diurnal combinations of either  $2.8^{\circ}/22.8^{\circ}$  C or  $2.8^{\circ}/17.8^{\circ}$  C. He stated temperatures of  $0^{\circ}$  to  $7.2^{\circ}$  C were best, while  $7.2^{\circ}$  to  $15.6^{\circ}$  C often gave incomplete bud-break and  $15.6^{\circ}$  to  $26.7^{\circ}$  C showed definite symptoms of prolonged dormancy. Intermittent chilling of 16 hr at  $3.9^{\circ}$  C and 8 hr at  $21.1^{\circ}$  C produced symptoms of prolonged dormancy on peaches when compared to a constant  $3.9^{\circ}$  C (71). Erez and Lavee (49) found alternating a high temperature of  $21^{\circ}$  C with a low temperature of  $5^{\circ}$  C in a daily cycle nullified the low temperature effect, but  $18^{\circ}$  C had no effect when alternated with  $6^{\circ}$  C. Peach buds responded better to a  $6^{\circ}/15^{\circ}$  C temperature regime than continuous  $4^{\circ}$  C (46). Bud-break was delayed when  $6^{\circ}$  C was alternated with  $21^{\circ}$  or  $24^{\circ}$  C (45, 46). Peach trees alternated between  $4.4^{\circ}$  C and  $15.5^{\circ}$  C at 48-hour intervals during rest began visible growth earlier



than those held at a constant  $4.4^{\circ}\text{C}$  (96). Weinberger (108) suggested the number of hours of partially effective temperatures from  $7.2^{\circ}$  to  $12.8^{\circ}\text{C}$  may have hastened rest breaking of peaches and higher maximum temperatures might have counteracted rest breaking temperatures but this action in delaying rest completion was more than simply preventing the occurrence of chilling (108). 'Tifblue' rabbiteye blueberry responded more quickly to natural diurnal conditions than to constant temperatures (90). It was shown in a later study a high temperature of  $18^{\circ}\text{C}$  did not nullify the effect of a  $7^{\circ}\text{C}$  low temperature on rabbiteye blueberry. A high temperature of  $23+3^{\circ}\text{C}$  slowed but did not nullify the low temperature effect (89).

The problem of prolonged dormancy has been recognized for many years but poorly understood (11, 20, 57, 70, 72, 82, 105, 107). When deciduous fruit trees receive inadequate chilling during rest, the result is delayed and sporadic foliation, nonviable flower parts and bud abscission (60, 105). This may lead to loss of the crop and weakening of the tree (15), and is particularly acute in mild climatic areas where the number of chilling hours varies widely from year to year. Higdon (57) noted bloom appeared later than normal over a longer period of time with misshapen flowers on inadequately chilled peach trees in South Carolina. Fruit were dropped in many cases because of a lack of leaves to support them. An increase in watersprout growth due to inactivity or death of terminal buds was also observed.

Similar effects were noted in Texas but bright sunshine and high UV radiation were mentioned as contributing factors (88). Jonkers (58), in 1979, hypothesized delayed foliation on apples and pears may also have been influenced by high temperatures during the preceding summer.

Temperatures often remain quite high for extended periods of time during winter months in mild climates. The effect of continuously high temperatures would most likely appear as a reversal of chilling resulting in either a loss of chill units or simply a temporary cessation of chill unit accumulation with a lag in resumption of chilling. Erez and Lavee (49) found interrupting the chilling period by 2 separate periods of 11 and 12 days each at 20° C did not inhibit bud-break of peach and greatly enhanced lateral vegetative bud-break. It was proposed there is a short duration after chilling initiation when high temperatures cause reversal and some fixation process prevents reversal after longer periods of chilling. Edgerton (40) observed a loss of cold hardiness in resting peach trees exposed to 7 days at 18.3° C, but they did not respond significantly to the same temperature over a shorter period of 1 to 4 days. These results are consistent with other data indicating counteraction of chilling accumulation by high temperatures (71, 106, 116).

Partially vernalized winter rye seems to be similarly affected in that acceleration of flowering can be partially annulled by temperatures above 15° C. The degree of reversal seems dependent upon the duration of the low temperature

treatment and the temperature level and duration of subsequent heat treatments. The vernalized condition appears to become progressively stabilized as the duration of the low temperature is extended (51, 78). Erez et al. (47) concluded chilling ( $4^{\circ}$  to  $6^{\circ}$  C) accumulated by peach leaf buds during the 20 to 40 hours prior to the onset of high temperatures ( $24^{\circ}$  C) was susceptible to high temperature negation. It is important to understand such effects in order to predict plant behavior accurately. This is especially critical in mild climates where the ultimate solution will come from using such information to improve breeding programs (84).

Growers in the Southeast face difficulties not usually experienced in the North because of the unique combinations of weather problems (22). There have been many attempts over the years to develop methods of breaking rest of fruit trees which receive inadequate winter chilling. Application of chemicals has received much attention. Several groups of materials were tested in the 1930's and 1940's as forcing sprays, including salts, oils and phenolic substances (82, 103). More recently, several research workers have reported a correctly timed thiourea spray can be effective in stimulating peach bud development in mild winters, both alone (13, 14) and in combination with  $\text{KNO}_3$  (113, 114). DNOC (4,6-dinitro-o-cresol) and DNCHP (dinex) also have rest-breaking properties (16, 50). Studies have been done using cytokinins (109), gibberellic acid ( $\text{GA}_3$ ) (27, 37, 98, 99) and potassium gibberellate (92). An understanding of the effects of various

temperature conditions on the rest period is a prerequisite both for predicting the necessity for treatment and for correctly timing chemical applications (82).

A more recent attempt at influencing the bloom of peaches by breaking rest is evaporative cooling by means of overhead sprinkling (35, 52). Trees in Florida were sprinkled during the rest period and cooled sufficiently to increase chill unit accumulation and advance the rest completion date (52). Similar work has been done with apples (2). Shading has also hastened flowering and foliation of low chilling peach and nectarine cultivars (19).

Westwood and Bjornstad (112) suggested the reduction in time required for breaking of rest of apples and pears may have been a result of leaching of some water-soluble substance, such as ABA, from dormant buds. Bauer et al. (8) compared the amounts of total and reducing sugars and proteins, as well as a number of mineral elements, in sprinkled and nonsprinkled 'Redhaven' peach trees. No significant differences were found but samples were taken late, thus differences may have been masked by new growth (8).

A decrease in starch and a corresponding increase in sugars have long been associated with cold acclimation in woody plants (38, 39, 41, 42, 43, 61, 62, 63, 64, 86, 87). Carbohydrates are probably one of the substances most easily leached from plants (95), thus changes in levels of soluble carbohydrates should give an indication of the amount of leaching obtained and its importance in the chemical or

metabolic adjustments that take place throughout the dormant period. Tukey (95) reported a wide range of materials, including inorganic minerals and organic substances such as amino acids, nucleic acids and growth regulators, could be leached by rain or mist. Dalbro (30) reported stems and branches of woody plants are capable of both uptake and loss of nutrients by leaching, even during the dormant season. The leaching of simple precursors may prove to be of even greater significance (94).

Loss of flower buds as the result of a late spring freeze is a problem associated with early bud development subsequent to high temperatures during the "post-rest" period of low chilling plants (21, 22). Various chemicals have been used in an attempt to delay bud development of fruit trees after rest is completed, gibberellins (27, 75), Alar (93) and ethephon (35, 76, 77) having been used with varying degrees of success.

Evaporative cooling has also been successfully employed as a means of delaying bloom and lessening the risk of damage from spring frost (1, 6, 8). Water is applied following rest termination, during the period of GDH acquisition. Peach bloom has been delayed by as much as 14 to 15 days following intermittent sprinkling after rest (21, 22, 65). Robertson and Stang (81) concluded the potential return for peaches was great enough to make this practice economically feasible. Similar results in bloom delay have been obtained with other deciduous fruits (1, 2, 23, 91, 115) with the delay in some instances also influencing fruit maturity (7, 24).

## CHAPTER I

### A PREDICTION MODEL FOR REST TERMINATION OF 'SUNGOLD' NECTARINE

#### Introduction

Temperature is a major factor limiting deciduous fruit production in the southeastern United States (15). Temperature fluctuations may result in either delayed and erratic foliation and flowering from insufficient chilling or frost damage to blossoms and wood when temperatures are cold enough to terminate rest too early. Unseasonably high temperatures often interrupt normal winter temperatures, both briefly and for extended periods of time. Physiological manipulation of plant development is possible through chemical applications and other cultural practices both to increase chilling in warm seasons and to delay bloom to avoid spring freezes (8, 19, 52). It is first necessary to understand how the plant responds to a wide range of environmental conditions before these methods may be used effectively.

A mathematically derived expression which relates temperature to rest completion by means of a model based on chill unit accumulation was developed in Utah (79), and was partially based on data accumulated in the Southeast on cultivars requiring 950 hours or more to terminate dormancy. This model is based on 6° C as the optimum chilling temperature.

Studies indicate that optimum chilling temperatures vary due to climatic conditions and/or cultivar differences. Some low chilling (i.e. 100-500 hours) peach cultivars grown in Florida and other mild climates respond to chilling at higher temperatures than cultivars requiring a longer chilling period (53). The Utah model is reasonably accurate only under environmental conditions similar to those where it was developed; therefore, modifications in the model are necessary for lower chilling cultivars.

The objective of this study was to examine responses of low chilling nectarines to chilling and non-chilling temperatures and incorporate this information into a model which would more accurately predict rest termination.

#### Materials and Methods

An experiment was initiated in December, 1979, to investigate the effectiveness of various temperature conditions for satisfying the chilling requirement of Prunus persica (L.) Batsch var. nectarina. Plants were 1-year-old rooted cuttings of 'Sungold' nectarine with a chilling requirement of approximately 550 hours (19). Plants were kept outdoors prior to the experiment and hours of exposure to 7.2° C and below were monitored.

Five computer controlled chambers were maintained at constant temperatures of 0.6°, 3.3°, 7.0°, 10.0° and 15.0° C. Chilling was applied in the dark. Three additional chambers were maintained at diurnally fluctuating temperatures with 10 hour day/14 hour night regimes of 30°/7° C, 15°/7° C

and 7°/0° C, using 40, 75 and 200 watt incandescent light bulbs, respectively, to maintain maximum temperature. (Actual exposure was 9 hours/13 hours with temperature transition periods of 1 hour). A maximum temperature  $\pm 1.25^{\circ}$  C was maintained in each chamber.

Each temperature treatment consisted of 40 plants placed randomly on a rack 10 cm above the floor of the chamber and watered as needed. Half of the plant material in each chamber was held continuously at the specified temperatures for the duration of their chilling periods. The remainder were removed after receiving half their chilling (e.g. after 175 hours for the 350-hour duration), held in the dark for 14 days at  $30^{\circ} \pm 1.0^{\circ}$  C, and returned to the chambers for completion of the chilling period.

Four plants were removed from the chambers at 100-hour increments from 350 to 750 chilling hours and placed in a greenhouse held at a day/night temperature regime of approximately  $27^{\circ}/13^{\circ}$  C. Plants were arranged randomly on a bench, watered as needed and rated weekly for floral and vegetative bud-break (Table 1).

A mathematical equation quantifying chill unit accumulation was then derived from combined floral bud-break data. This equation related temperature to days required for bud-break. A second equation was then generated to correlate temperature with hourly chill unit values. The model was tested for accuracy and modified, using orchard temperature data collected hourly over the previous 2 winters from 'Sungold' and 'Sunlite' nectarine trees.



Table 1. Rating scale for floral and vegetative bud-break of nectarine.

Rating	Developmental stage	
	Floral	Vegetative
1	no response	no response
2	bud swell to green tip	bud swell
3	pink tip	green tip
4	popcorn (balloon stage)	leaves rolled
5	open blossom	leaves expanded

### Results and Discussion

Response surfaces or contours which best describe the relationship between chilling temperature and days required for bud-break were developed by regression analysis. There was no significant interaction between chilling temperature and chilling duration in the original analysis; therefore, the response contour derived for each chilling duration is affected by all other chilling durations; hence, the similarity of the curves. Data indicate that a rating of 2.5 (bud-break) for floral buds was reached as fast or faster at  $10^{\circ}\text{C}$  when compared to  $7^{\circ}\text{C}$  at most chilling durations. This trend was evident both in plants held at continuous chilling temperatures (Fig. 1) and those subjected to high temperature interruption (Fig. 2), although there were no significant differences among any temperatures for the latter. Bud-break occurred in the continuous  $15^{\circ}\text{C}$  treatment only at the longest chilling duration. These results are similar to those of Weldon (110), who found  $9.6^{\circ}\text{C}$ - $9.8^{\circ}\text{C}$  was the threshold temperature for chilling accumulation for peaches in California. Gurdian and Biggs (53), working with low chilling peaches (100-200 hours), noted the rate of resumption of bud growth was not different on plants from  $7.2^{\circ}\text{C}$  and  $12.8^{\circ}\text{C}$  chilling treatments. Rate of bud-break increased as chilling was increased to 480 hours. Increasing the chilling duration to 750 hours increased the rate of floral bud-break in the present study but this increase was progressively less with each 100 hour increment. It has previously been shown that the duration of exposure to

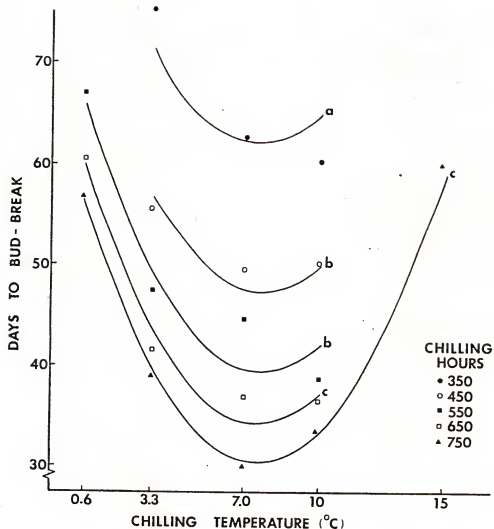


Fig. 1. Floral bud-break response contours for 'Sungold' nectarine at continuous chilling temperatures. (Contour separation between chilling durations by Duncan's multiple range test, 5% level.)

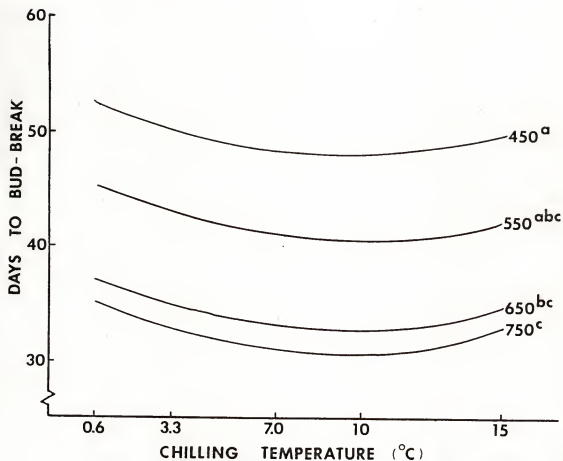


Fig. 2. Floral bud-break response contours for 'Sungold' nectarine at 4 chilling durations interrupted by 14 days at 30° C. (Contour separation between chilling durations by Duncan's multiple range test, 5% level.)

either  $7.2^{\circ}$  or  $12.8^{\circ}$  C, while increasing the rate of bud growth, had little influence on the final number of buds terminating dormancy on low chilling peaches (53). The present data show a similar response at constant temperatures of  $7^{\circ}$  and  $10^{\circ}$  C. Continuous temperature treatments at  $0.6^{\circ}$ ,  $3.3^{\circ}$  and  $15.0^{\circ}$  C failed to reach the same level of bud activity as  $7^{\circ}$  and  $10^{\circ}$  C, even after 60 days under forcing conditions. Plants subjected to the interruption period, although breaking more rapidly initially, failed to reach a level of bud activity comparable to those under continuous temperature treatments (Fig. 3). Chilling duration influenced final bud activity levels in all interruption treatments.

Chilling negation by high temperatures has been shown to vary considerably. Weinberger (106) found both vegetative and floral bud-break could be retarded by exposing a peach branch to 3 days over  $37.8^{\circ}$  C plus 9 days over  $32.2^{\circ}$  C. Erez et al. (47), however, noted 2 separate interruption periods of 11 and 12 days at  $20^{\circ}$  C showed no nullifying effect. The fact that plants in the present study which were given an interruption period never reached maximum bud activity may indicate some chilling negation or reversal was obtained but was only evident in a fraction of the buds, since bud-break activity recorded was an average of 4 replications. This may be a response similar to one noted in cases of prolonged dormancy where, although bud opening is usually irregularly delayed, some buds may begin to open rapidly but fail to develop further.

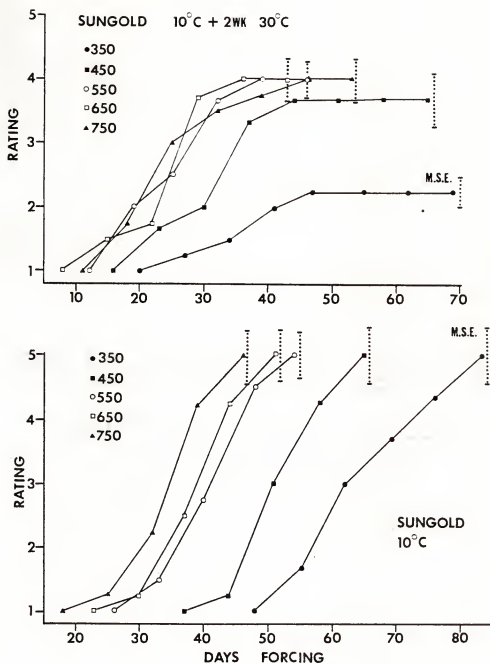


Fig. 3. Floral bud-break of 'Sungold' nectarine plants held for 5 chilling durations at chilling temperatures of 10° C plus 2 weeks at 30° C and continuous 10° C.

In contrast to the continuous temperature treatments, there was no visible bud activity on plants given 350 hours chilling with an interruption (Fig. 2). This helps substantiate the theory that a minimum amount of chilling must be received before a "temperature-dependent fixation process" can occur (47). In this case, the 175 chilling hours received prior to the interruption period may not have been adequate for the hypothetical fixation to occur; thus, the chilling obtained was still susceptible to negation or reversal. A similar mechanism has been observed when partially vernalized winter rye is subjected to prolonged heat treatment. The vernalized condition appears to become more stable as the duration of exposure to low temperature is increased; thus, the effect of the reversal is dependent upon the duration of the preceding low temperature treatment (51). Purvis and Gregory (78) theorized there is a high temperature reversible intermediate within a low-temperature-induced reaction from precursor to product. The condition becomes more stable and irreversible as vernalization proceeds and more product is generated. A similar mechanism may be taking place during the chilling process.

Floral bud-break was faster after exposure to  $7^{\circ}/0^{\circ}$  C and  $15^{\circ}/7^{\circ}$  C regimes than  $30^{\circ}/7^{\circ}$  C (Table 2). Comparing this to corresponding constant temperature treatments, buds completed rest and opened at  $7^{\circ}/0^{\circ}$  C faster than  $0.6^{\circ}$  C but not as rapidly as  $7^{\circ}$  C. Bud-break following exposure to a  $15^{\circ}/7^{\circ}$  C regime was intermediate between constant  $7^{\circ}$  and  $15^{\circ}$  C.

Table 2. Days to floral bud-break of 'Sungold' nectarine under continuous chilling treatments.

Chilling temp (°C)	Days to bud-break <sup>z</sup>				
	Chilling hours				
	350	450	550	650	750
0.6	--- <sup>y</sup>	---	67a <sup>x</sup>	61a	57ab
7.0/0 <sup>w</sup>	---	61a	53b	50b	40cd
7.0	63	50b	45b	37c	30d
15.0/7.0	---	---	46b	42bc	47bc
15.0	---	---	---	---	60a

<sup>z</sup>Rating of 2.5.

<sup>y</sup>Failed to reach mean bud-break rating of 2.5.

<sup>x</sup>Mean separation in columns by Duncan's multiple range test, 5% level.

<sup>w</sup>Day/night.



No bud-break was evident after the non-interrupted  $30^{\circ}/7^{\circ}$  C treatment. Any chilling obtained was apparently nullified, as no bud-break was evident even after 67 days of forcing for the highest chilling duration. It would appear that occasional high temperatures are not as antagonistic to the rest period as frequent periods of high temperatures following short periods of chilling, since  $30^{\circ}$  C did not completely nullify chilling when given as a 2 week interruption period. A similar response was noted on 'Redskin' and 'Redhaven' peaches where a daily cycle of 8 hours at  $24^{\circ}$ /16 hours at  $6^{\circ}$  C resulted in no lateral leaf bud-break (46). A 2- or 3-day exposure to  $24^{\circ}$  C cycled with 4 to 6 days at  $4-6^{\circ}$  C resulted in good bud-break, while little activity was obtained following 2 days of chilling cycled with 1 day at  $24^{\circ}$  C. It was concluded the chilling accumulated 20-40 hours prior to high temperature exposure was susceptible to negation (47).

High temperature did not have the complete inhibitory effect as observed in previous studies, but it must be noted the majority of such work was done using cultivars with 750 to 950 chilling hour requirements. Low chilling peaches and nectarines reach an acclimation base at a higher temperature (17, 18); thus, the same trend is likely for the chilling requirement and it would be expected that such cultivars would be more tolerant of high temperatures.

There were no significant differences in vegetative bud-break among chilling temperatures under both continuous and interruption treatments (Table 3). No bud-break occurred

following exposure to either 0.6° or 15.0° C. Bud-break was more rapid on treatments exposed to the interruption. In contrast to floral buds, vegetative buds given an interruption reached a final bud activity level similar to those given continuous temperatures. Final bud-break activity was dependent upon the chilling duration for constant treatments, but chilling duration had no significant influence on bud-break in interruption treatments. Response of vegetative buds exposed to diurnal regimes was highly variable. In general, vegetative bud-break appeared more inhibited by short exposure to high temperature than extended exposure. Overcash (72) found that a high temperature of 21° C alternated with 4° C in a daily cycle slowed vegetative bud-break of 'Sunhigh' and 'Redhaven' peach. Similar results were noted on pears in California (9).

The temperature-chill unit model derived from the combined floral bud-break data is presented with the Utah model for comparison (Fig. 4). The high chilling curve representing effective bud temperature is based on instrument shelter temperatures (66). Temperatures and corresponding chill unit values are also presented (Table 4). The low chilling model is broader and shows a higher optimum peak when compared to the Utah model. The high chilling curve based on bud temperature reaches maximum negation (-1.0 C.U.) at the same temperature as the low chilling model. There is no difference in response at the extreme low end of the curve, approaching -1.0° C (0 C.U.). This suggests the temperature

Table 3. Days to vegetative bud-break of 'Sungold' nectarine.

Treatment	Chilling hours	Days to bud-break <sup>z</sup>		
		Chilling temperature (°C)		
		3.3	7.0	10.0
Continuous chilling	450	68.7a <sup>y</sup>	67.3a	67.0a
	550	54.6b	54.2b	54.0b
	650	54.7b	54.4b	54.1b
	750	41.2c	40.9c	40.6c
Chilling interrupted by 14 days at 30° C	450	--- <sup>x</sup>	36.5	---
	550	---	20.4	20.3
	650	25.1	24.9	24.8
	750	26.7	26.6	26.5

<sup>z</sup> Rating of 2.5.

<sup>y</sup> Mean separation in columns by Duncan's multiple range test, 5% level.

<sup>x</sup> Failed to reach mean rating of 2.5.

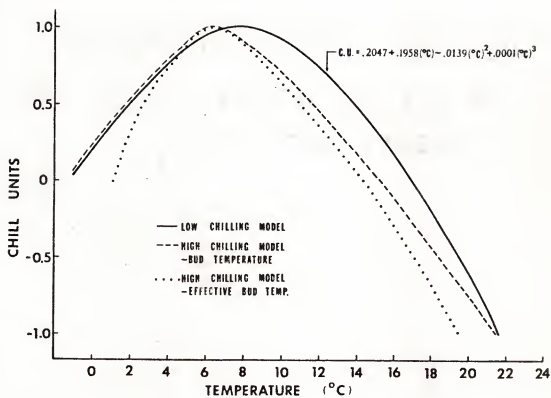


Fig. 4. Temperature - chill unit model for 'Sungold' nectarine (550 hr) with Utah high chilling model for comparison. (Utah data from Lombard and Richardson (66).)

Table 4. Corresponding temperature and chill unit values from low chilling model.

Chill units	Temperature (°C)
0	-1.0
0.5	1.8
1.0	8.0
0.5	14.0
0	17.0
-0.5	19.5
-1.0	21.5

threshold for maximum chilling negation may be relatively consistent within a species, while cultivar differences are most apparent at the optimum temperature and in the positive chill unit region at temperatures above the optimum.

The shift in optimum chilling temperature of  $2^{\circ}\text{C}$  (from  $6^{\circ}$  to  $8^{\circ}\text{C}$ ) is significant; however, the portion of the curve where the greatest divergence is noted,  $8^{\circ}$  to  $18^{\circ}\text{C}$ , may be even more important in total chilling accumulation. Winter temperatures in warm climates often fall within this range; hence, their contribution to chilling cannot be ignored. Exclusion of the area between the curves, by assigning smaller chill unit values within this temperature range, may be the reason for failure of high chilling models to predict rest completion under mild conditions.

Work of Couvillon et al. (29) indicates the rest period and chilling requirement of rooted cuttings does not differ significantly from those of mature trees; thus, the model was considered applicable to established trees. The model was modified and tested for accuracy using orchard temperature data for 'Sungold' (550 hour) and 'Sunlite' (450 hour) nectarines. The low chilling model was more accurate as compared to other methods of predicting rest completion (Table 5). In all cases, prediction was more accurate when chill unit summation was initiated on the day in fall following the day of the largest negative chill unit accumulation, as suggested by Richardson et al. (79). Chill unit summation was initiated on December 5 in 1978-79 and on November 3 in 1979-80. Accuracy

Table 5. Actual and predicted dates of rest completion using various computation methods for 'Sungold' and 'Sunlite' nectarine.

Computation method	Date of rest termination	
	'Sungold' (1978-79)	'Sunlite' (1979-80)
Actual (orchard forcing data)	43 <sup>z</sup> (Feb. 12)	37 (Feb. 6)
Hours $\leq 7.2^{\circ}\text{C}$	36 (Feb. 5)	23 (Jan. 23)
Hours $\leq 10.0^{\circ}\text{C}$	23 (Jan. 23)	02 (Jan. 2)
High chilling model- $6^{\circ}\text{C}$ base	-- <sup>x</sup>	--
High chilling model- $10^{\circ}\text{C}$ base <sup>y</sup>	23 (Jan. 23)	362 (Dec. 28)
Low chilling model- $8^{\circ}\text{C}$ base	41 (Feb. 10)	31 (Jan. 31)

<sup>z</sup>Julian date.

<sup>y</sup>Using curve of high chilling model shifted to obtain a  $10^{\circ}\text{C}$  optimum with a range of  $2^{\circ}\text{C}$  (0 C.U.) to  $26.7^{\circ}\text{C}$  (-1 C.U.).

<sup>x</sup>Failed to accumulate adequate chilling units by bloom.

of the model was reduced when chill unit accumulation was initiated at leaf fall. It is interesting to note the variation in the time between these 2 dates. The day of largest negative chill unit accumulation was approximately 4 weeks after leaf fall in the 1978-79 season, while this difference was only 2 days in the 1979-80 season. Such variation will undoubtedly influence the accuracy of the model, necessitating further investigation to determine at what point in the plants' rest period chilling does become effective.

Data presented here substantiate the importance of the cycle length, maximum temperature and preceding exposure to chilling in the reversal or negation of chilling. This research indicates there are cultivar-dependent differences in chilling temperature effectiveness. Such information must be considered in the development of accurate rest prediction models.



## CHAPTER II

### INFLUENCE OF TEMPERATURE AND CULTIVAR ON THE CHILLING REQUIREMENT OF RABBITEYE BLUEBERRY

#### Introduction

Rabbiteye blueberry plantings in Florida often receive insufficient winter chilling, resulting in poor fruiting and growth (85). Previous work has shown that 'Woodard' and 'Tifblue' require approximately 400 and 600 hours, respectively, of continuous chilling for normal flowering (90). Little is known about specific temperature effects such as optimum chilling temperature, the range of temperatures which are effective in satisfying chilling and the effect of high temperatures interspersed in the chilling period. The effect of high temperature interruption on the chilling period of peach depends upon the temperature, length of exposure and preceding exposure to chilling temperatures (46, 47). Similar work with blueberries (89) has shown that daily exposure to 10 hours at  $23^{\circ} \pm 3^{\circ}$  C alternated with low temperature slowed the chilling process while  $18^{\circ}$  C resulted in no slowing effect.

Determining specific temperature effects on satisfying the chilling requirement is a prerequisite to development of rest prediction models for blueberries. Accurate models would facilitate use of chemical and cultural practices to prevent problems associated with prolonged dormancy. This study was initiated to determine if cultivar differences exist in chilling temperature effectiveness, and to better

define the effect of various chilling temperatures on satisfying the chilling requirement of 3 commercially important rabbiteye blueberry cultivars.

#### Materials and Methods

Plant material included 1 year-old rooted cuttings of 'Woodard' rabbiteye blueberry and 15 cm dormant budsticks of cultivars 'Woodard', 'Bluegem' and 'Tifblue'. Plants were kept outdoors prior to the experiment and hours' exposure to  $7.2^{\circ}\text{C}$  and below was recorded. Leaves which had not abscised were removed prior to chilling. Five computer-controlled temperature chambers were maintained at constant temperatures of  $0.6^{\circ}$ ,  $3.3^{\circ}$ ,  $7.0^{\circ}$ ,  $10.0^{\circ}$  and  $15.0^{\circ}\text{C}$ . Three additional chambers were maintained at diurnally fluctuating temperatures with 10 hour/14 hour regimes of  $30^{\circ}/7^{\circ}$ ,  $15^{\circ}/7^{\circ}$  and  $7^{\circ}/0^{\circ}\text{C}$ . Temperatures in each chamber were maintained at  $\pm 1.25^{\circ}\text{C}$ .

Each temperature chamber contained 40 plants and 60 budsticks of designated cultivars. Plants were placed randomly on a rack 10 cm above the chamber floor and watered as needed. Budsticks were placed in polyethylene bags with their basal ends in moistened sphagnum peat moss and interspersed randomly among plants in the chambers. Half the plant material in each chamber was held at the specified temperature continuously throughout their chilling periods. The remainder were removed after receiving half their designated chilling (e.g. after 125 hours for the 250 hour

duration), held for 14 days at  $30^{\circ} \pm 1.0^{\circ}$  C, and returned to the chambers for completion of chilling.

Four plants or 6 cuttings were removed from each chamber at 100 hour increments ranging from 250 to 650 hours for 'Woodard' and 'Bluegem' and 450 to 850 hours for 'Tifblue'. Plants were then placed randomly on a bench in a greenhouse maintained at a day/night temperature regime of approximately  $27^{\circ}/13^{\circ}$  C and watered as needed. Budsticks were placed in a bed of peat-perlite under intermittent mist. All plant material was rated weekly for floral and vegetative bud-break (Table 6).

### Results and Discussion

Terminal floral bud-break was similar for all cultivars at constant temperatures of  $0.6^{\circ}$ ,  $3.3^{\circ}$ ,  $7.0^{\circ}$  and  $10.0^{\circ}$  C. 'Tifblue' did not respond as well to  $15.0^{\circ}$  C as the lower chilling cultivars, with no visible bud activity evident following either 450 or 550 hours exposure to  $15.0^{\circ}$  C (Table 7). The same effect was evident in the diurnal treatments. 'Woodard', 'Bluegem' and 'Tifblue' responded similarly to  $7^{\circ}/0^{\circ}$  C, but 'Tifblue' did not respond as rapidly following chilling at  $15^{\circ}/7^{\circ}$  C. Differences among cultivars were more apparent on lateral floral bud-break (Table 8). 'Tifblue' did not respond to constant  $15.0^{\circ}$  C or diurnal  $15^{\circ}/7^{\circ}$  C temperatures and responded to constant  $10.0^{\circ}$  C only when exposed to the maximum chilling duration, 850 hours. These results indicate a narrower range of effective chilling temperatures for 'Tifblue', suggesting that 'Woodard' and

Table 6. Rating scale for floral and vegetative bud-break of rabbiteye blueberry.

Rating	Developmental stage	
	Floral	Vegetative
1	no response	no response
2	bud swell	green tip
3	individual blossoms visible	leaves unrolling
4	corolla extended 50%	$\leq$ 5cm shoot growth
5	open blossom	$>$ 5cm shoot growth

Table 7. Days to terminal floral bud-break of budsticks of 3 rabbiteye blueberry cultivars at continuous chilling temperatures.

Chilling hours <sup>x</sup>	Days to bud-break <sup>z</sup>							
	Chilling temperature regime (°C) <sup>w</sup>							
	0.6	3.3	7.0	10.0	15.0	0/7	7/15	7/30
'Woodard'								
250	47	30	40	49	54	75	71	-- <sup>y</sup>
350	36	40	29	38	50	40	48	--
450	29	22	23	41	44	40	43	--
550	25	21	26	28	26	31	26	--
650	22	24	20	26	33	27	24	--
'Bluegem'								
250	40	26	32	33	47	49	36	--
350	43	45	36	31	43	32	33	--
450	30	18	18	27	39	29	32	--
550	24	14	14	24	39	28	28	--
650	21	10	14	31	38	33	31	50
'Tifblue'								
450	51	44	50	51	--	50	--	--
550	40	35	51	53	--	40	63	--
650	40	31	31	45	52	40	48	--
750	31	27	27	41	55	31	38	--
850	28	22	22	27	41	28	33	--

<sup>z</sup>Rating of 2.0.

<sup>y</sup>No visible bud activity.

<sup>x</sup>There was a significant linear trend for chilling duration at the 5% level for all cultivars as determined by regression analysis of variance.

<sup>w</sup>Effect of temperature was nonsignificant for 'Woodard' and 'Bluegem' and showed a significant quadratic trend for 'Tifblue' at the 1% level as determined by regression analysis of variance.

Table 8. Days to lateral floral bud-break of budsticks of 3 rabbiteye blueberry cultivars at continuous chilling temperatures.

Chilling hours <sup>x</sup>	Days to bud-break <sup>z</sup>							
	Chilling temperature regime (°C) <sup>w</sup>							
	0.6	3.3	7.0	10.0	15.0	0/7	7/15	7/30
'Woodard'								
250	-- <sup>y</sup>	--	--	75	--	--	--	--
350	--	--	--	64	--	--	--	--
450	--	46	60	53	--	53	--	--
550	--	49	52	49	49	58	--	--
650	--	36	43	45	45	45	38	--
'Bluegem'								
250	--	68	61	65	--	61	--	--
350	--	50	64	43	37	64	--	--
450	60	39	46	46	53	46	39	--
550	40	28	49	42	56	44	49	--
650	38	31	45	38	52	31	40	--
'Tifblue'								
450	--	35	--	--	--	--	--	--
550	--	56	--	--	--	--	--	--
650	--	45	59	--	--	59	--	--
750	41	44	45	--	--	41	--	--
850	36	36	29	50	--	38	--	--

<sup>z</sup>Rating of 2.0.

<sup>y</sup>No visible bud activity.

<sup>x</sup>There was a significant linear trend for chilling duration at the 1% level for all cultivars as determined by regression analysis of variance.

<sup>w</sup>Effect of temperature was nonsignificant for 'Woodard' and 'Bluegem' and showed a significant quadratic trend for 'Tifblue' at the 5% level as determined by regression analysis of variance.

'Bluegem' are better adapted to mild climatic conditions due to a broader temperature range over which chilling is effective. This effect is most notable at the upper limit of the range.

Although 'Woodard' and 'Bluegem' are both low chilling cultivars (based on bloom dates), terminal flower buds of 'Bluegem' opened faster under most temperature conditions. This trend was evident following both continuous and interrupted chilling treatments. This may be a result of either slight differences in chilling requirement or differences in the amount or means of accumulation of growing-degree-hours required for bud-break. Lateral bud-break was also more rapid on 'Bluegem' than 'Woodard' under similar chilling conditions. The lack of activity under low chilling durations and certain temperature regimes may be due to poor survival of budsticks, limiting the time span over which observations could be made. Terminal bud-break occurred more rapidly than lateral bud-break for all cultivars and treatments. This response should be considered when assigning chilling requirements.

There was a significant quadratic relationship between temperature and days to floral bud-break of 'Woodard' rooted cuttings exposed to continuous temperature treatments, but specific effects were variable depending upon the amount of chilling received (Table 9). The lack of temperature significance for budsticks may be attributed to physiological problems associated with absence of a root system or other

Table 9. Days to floral bud-break of rooted cuttings of 'Woodard' rabbiteye blueberry under continuous and interrupted chilling conditions.

Chilling temperature (°C)	Days to bud-break <sup>z</sup>									
	Continuous chilling					Chilling + 14 days at 30°C				
	Chilling hours									
	250	350	450	550	650	250	350	450	550	650
0.6	59.5ab <sup>y</sup>	56.7ab	42.3ab	42.5a	42.3a	55.8a	47.5	37.3ab	24.7	28.0
3.3	53.7ab	33.3c	44.5a	32.0a	30.0c	40.0ab	42.3	36.0ab	23.8	8.3
7.0	45.8b	33.3c	34.0abc	19.8c	20.5d	19.0b	38.5	37.7ab	23.7	12.3
10.0	63.0ab	36.5bc	42.0ab	20.0bc	38.3abc	44.5ab	18.0	17.5b	20.8	14.6
15.0	69.0a	48.0abc	31.7bc	34.5a	31.5bc	50.5ab	35.3	31.7ab	32.0	24.7
0/7	65.0a	53.3abc	32.5bc	34.0a	40.0ab	44.5ab	29.8	40.8a	24.0	37.0
7/15	49.7a	53.7abc	27.3c	42.5a	39.7ab	54.7a	39.0	40.7a	19.5	16.3
7/30	62.7ab	69.0a	28.5bc	31.7ab	34.0abc	--x	52.5	41.7a	40.0	35.0

<sup>z</sup>Rating of 2.5.

<sup>y</sup>Mean separation within columns by Duncan's multiple range test, 5% level.

<sup>x</sup>No visible bud activity.



problems encountered with explants, such as dissication. This may limit applicability of budstick chilling data to mature plants. Floral bud-break of rooted cuttings subjected to a high temperature interruption occurred faster than those given continuous chilling, but a similar level of activity was reached for both regimes. Spiers and Draper (90) noted that increasing the number of chilling hours enhanced floral bud-break of 'Tifblue'. In this study, there was a significant reduction in number of days to bud-break under most temperature treatments for both 'Woodard' and 'Bluegem' as chilling was increased from 250 to 650 hours. The same was true for 'Tifblue' as chilling was increased from 450 to 850 hours.

The effect of temperature was not as pronounced for vegetative as floral bud-break (Table 10). There were few significant differences between temperatures under continuous chilling. There was, however, a highly significant linear trend for chilling duration in both continuous and interruption treatments. Days required for bud-break decreased as chilling increased. Spiers (89) and Spiers and Draper (90) found floral buds of 'Tifblue' were influenced more than vegetative buds by insufficient chilling under constant temperatures. This difference was not noted in the present study. Vegetative bud-break was enhanced initially when plants were subjected to a high interruption temperature, but the final level of bud activity was similar to those in continuous treatments.

Table 10. Days to vegetative bud-break of rooted cuttings of 'Woodard' rabbiteye blue-berry under continuous and interrupted chilling conditions.

Chilling temperature (°C)	Days to bud-break <sup>z</sup>									
	Continuous chilling					Chilling + 14 days at 30°C				
	Chilling hours									
	250	350	450	550	650	250	350	450	550	650
0.6	65.5ab <sup>y</sup>	46.0	54.5	48.0a	44.5a	39.0ab	42.5a	30.3ab	25.8	21.0ab
3.3	62.0ab	56.3	50.0	42.0ab	42.0a	52.0a	30.3ab	24.0ab	23.5	17.8b
7.0	61.3ab	48.3	50.8	33.0c	31.0b	36.0ab	20.0b	25.5ab	21.8	14.0b
10.0	63.0ab	60.7	50.8	37.8bc	38.6ab	33.3ab	14.8b	17.3b	21.0	18.8b
15.0	64.7ab	53.0	50.3	44.3ab	40.3a	41.7ab	22.5b	28.0ab	22.5	19.5b
0/7	69.5a	56.0	52.8	39.3bc	40.7a	48.7ab	39.8a	34.7ab	20.5	19.0b
15/7	52.3b	58.3	46.3	42.7ab	41.5a	30.5b	23.0b	24.5ab	21.3	19.5b
30/7	65.5ab	58.0	54.5	34.5bc	34.5bc	41.7ab	28.0ab	35.0a	23.7	28.8a

<sup>z</sup>Rating of 2.5.<sup>y</sup>Mean separation within columns by Duncan's multiple range test, 5% level.

Exposure to diurnal regimes resulted in vegetative bud-break similar to that obtained under constant temperatures. A diurnal regime of  $15^{\circ}/7^{\circ}$  C was generally more effective in satisfying rest than  $7^{\circ}/0^{\circ}$  or  $30^{\circ}/7^{\circ}$  C for 250, 350 or 450, but not 550 or 650, chilling hour durations. Exposure to  $7^{\circ}/0^{\circ}$  C resulted in bud-break intermediate to  $0.6^{\circ}$  and  $7.0^{\circ}$  C constant treatments only when given at least 450 hours chilling. The  $7^{\circ}/0^{\circ}$  C regime slowed bud-break under insufficient chilling conditions of 250 or 350 hours. These results are similar to those with peaches where a  $15^{\circ}/6^{\circ}$  C chilling regime was more efficient than continuous chilling at  $4^{\circ}$  C (46). Exposure to  $30^{\circ}$  C in a daily cycle or a 14-day interruption did not result in chilling negation. This increased "tolerance" to high temperature is also indicated by the fact that bud-break response to constant  $15^{\circ}$  C was not significantly different from other constant temperatures.

Data presented herein indicate there are differences, not only in chilling requirement, but also in effectiveness of various chilling temperatures in satisfying the rest requirement of low chilling rabbiteye blueberry cultivars.

### CHAPTER III

#### INFLUENCE OF EVAPORATIVE COOLING DURING REST ON BUD DEVELOPMENT OF 'SUNGOLD' AND 'SUNLITE' NECTARINE

##### Introduction

Delayed and sporadic foliation and fruiting of peach and nectarine plantings in the Southeast are problems associated with inadequate winter chilling. There have been many attempts to influence bloom of deciduous fruit trees grown in warm climates where temperatures are often borderline for satisfying the chilling requirement (19, 49, 52, 82, 105). Evaporative cooling by overhead sprinkling has been shown to cool the tree sufficiently to increase chill unit accumulation and advance the date of rest completion (52). Recent studies have indicated that greater differences in bloom are obtained than indicated by accumulation of chill units (19,52). This discrepancy in time required for breaking rest may be a result of leaching of some water-soluble substance from the dormant tree (111). Increased water in the root zone of sprinkled trees may also be contributing to the observed response. A mathematical model relating temperature to chill unit accumulation would be useful for predicting both the necessity and proper timing for techniques to advance the date of rest termination.

The purpose of this study was to determine the effectiveness of sprinkling during rest to increase chill unit accumulation of low chilling nectarines, separate the effects of water applied to the tree canopy versus that applied to the root system and monitor changes in soluble carbohydrates and mineral elements as an indication of leaching.

#### Materials and Methods

Blocks of six 10-year-old 'Sungold' nectarine trees, with a chilling requirement of approximately 550 hours, were selected for 5 treatments in 1978-79 as follows: S-sprinkled overhead; P-sprinkled with plastic and mulch under trees; SC-soaker hoses (water only to roots); PC-nonsprinkled with plastic and mulch; and, C-nonsprinkled control. Five overhead sprinklers equipped with Nelson "Alpha II" 3.175 mm nozzles were placed in a combined block of 12 sprinkled trees. Sprinklers were controlled by a timeclock wired to a Thermistemp Model 64RC temperature sensor. Sprinkling was initiated November 3, just after natural leaf fall. Water was scheduled for 2 min on/8 min off between 8 AM and 6 PM whenever air temperature exceeded 10<sup>0</sup> C. Water output was approximately 11.5 liters/min. Water for treatment SC was applied through soaker hoses placed under the trees within the drip-line and controlled by timeclock. Soaker hoses were turned on November 10. The SC treatment received water at night for variable periods of time, depending upon soil moisture levels and amount of water applied to sprinkled

treatments S and P. Water use by all treatments was monitored with water meters placed in irrigation lines. Differences in soil moisture levels between treatments were compared at depths of 0.3, 0.6, 0.9, 1.2 and 1.5 m with a Troxler Model No. 1255 neutron probe. Plastic and mulched treatments consisted of .015 cm (6 mil) black polyethylene secured under the block of 6 trees and covered with a 7.6 cm layer of sawdust to reduce heat reradiation from the plastic.

Scaffold temperatures were sensed as an average of 4 thermocouples inserted at the cardinal points in fruiting wood of one tree in each treatment. Soil temperatures were monitored with thermocouples at depths of 10 and 20 cm under one tree per treatment. All thermocouples were 24-gauge copper-constantan. Temperatures were recorded hourly on a Leeds-Northrup 24-point recorder located in an instrument shelter in the orchard.

Water was turned off on February 1 when calculations of hours at 7.2° C and below indicated sprinkled trees had received 550 hours of chilling. Two 50-60 cm long budsticks were cut weekly from each treatment beginning in December, placed with their basal ends in water and forced in a greenhouse at 30°/16° C day/night. Cuts were renewed and water changed weekly at which time observations were recorded on floral and vegetative bud-break (Chapter 1, Table 1). Limbs were tagged in the orchard and rated weekly for floral and vegetative bud-break at the first sign of visible bud activity. Fruit counts were made on two 2 m limbs per tree and

a total of 30 fruit from each treatment were weighed prior to thinning to determine if changes in bloom date were carried over to fruit development.

Treatments in 1979-80 on blocks of six 4-year-old 'Sun-lite' nectarine trees, with a chilling requirement of approximately 450 hours, were the same as those used in 1978-79, except Rainbird Series 1600 sprinkler nozzles were mounted on risers extending through the canopy of individual trees for sprinkled treatments. Treatments were initiated November 4 and water output was approximately 9 liters/min. Sprinkling was controlled as in the previous season and was scheduled for 0.5 min on/14.5 min off between 8:30 AM and 5:30 PM. The decrease in wetting time was due to increased coverage obtained with individual sprinklers and differences in pattern and amount of water from the nozzles as compared to those used in 1978-79. Air, soil and scaffold temperatures were monitored as in 1978-79. Water was turned off on January 4 when sprinkled trees had received a calculated 450 hours at  $7.2^{\circ}\text{C}$  and below. Bud-break data were recorded as described for 1978-79.

Chill unit computations were made using hours  $\leq 7.2^{\circ}\text{C}$ ,  $\leq 10.0^{\circ}\text{C}$ , the Utah chill unit model (79) and the model developed for low chilling Florida peaches and nectarines (see Chapter I).

Samples of one g of flower buds were collected monthly from 4 trees per treatment from November to March during the winters of 1978-79 and 1979-80. Buds were placed

immediately in liquid  $N_2$  and were later transferred to a freezer and held at  $-20^{\circ} C$  until they were analyzed. A modified Anthrone reagent method similar to that of Morris (67) was used for soluble carbohydrate analysis. Bud samples were extracted 3 times with 10 ml absolute methanol at  $70^{\circ} C$  for a total of 45 min. The extract was brought to a volume of 10 ml with methanol and filtered through Whatman # 1 paper. Three 1 ml aliquots were then evaporated to dryness and 0.5 ml methylene chloride and 0.5 ml distilled water were added to each. This mixture was shaken and centrifuged for 5 min at 5000 rpm. Desired aliquots (either 10 or 20  $\mu l$ ) were drawn from the aqueous layer and added to test tubes containing 2 ml anthrone solution (1:1 (w:v) anthrone in conc.  $H_2SO_4$ ) and distilled water to give a final volume of 3 ml. Serial dilutions of 20 to 80 ppm were prepared from a 100 ppm glucose stock solution. Tissue sample solutions and standard solutions were kept in an ice bath. All solutions were shaken uniformly and placed in a  $90^{\circ} C$  water bath for 10 min, brought to room temperature in a  $25^{\circ} C$  water bath and held there until readings were completed. Absorbance was read at 630 nm on a Beckman Model 30 Spectrophotometer. Concentration of soluble carbohydrates in the tissue was determined by comparing readings to a glucose standard curve based on the standard solutions.

Bud and wood samples were collected monthly from 4 trees per treatment from November 1979 through February



1980 from 'Sunlite' trees. Bud samples consisted of 0.5 g of flower buds, and wood samples were a composite of six 15 cm long fruiting wood twigs per tree. Buds and twigs (cut into 3 cm lengths) were dried in a Thelco forced air oven at 100° C for 72 hours. Dried tissue was ground in a Wiley mill to pass a 20 mesh screen. Weighed tissues, 0.5 g bud tissue and 1.0 g wood tissue, were then ashed in a Lindberg Model 16 muffle furnace for 0.5 hour at 200° C and 7.5 hours at 475° C and cooled overnight. Resultant ash was then dissolved in 10 ml 1.0 N HCl, filtered through Whatman No. 4 paper and brought to a volume of 25 ml with 1.0 N HCl. Concentrations of Ca, Mg, K, Mn, Na and Fe were analyzed on a Perkins-Elmer Model 603 Atomic Absorption Spectrophotometer and P on a Technicon Auto Analyzer.

### Results and Discussion

Sprinkling provided a cooling effect of up to 4.3° C as evidenced by average weekly maximum temperatures of control and sprinkled trees (Fig. 5). This decrease in temperature should have effected some change in the chilling period resulting in differences in bud-break. Terminal and lateral leaf emergence in the orchard were advanced 5 and 6 days, respectively, on sprinkled treatments in 1978-79, using 50% emergence as a reference point (Fig. 6). Other treatments were similar to control trees. Visible bud activity began earlier in 1979-80 on sprinkled treatments but a hard freeze killed buds before bloom.

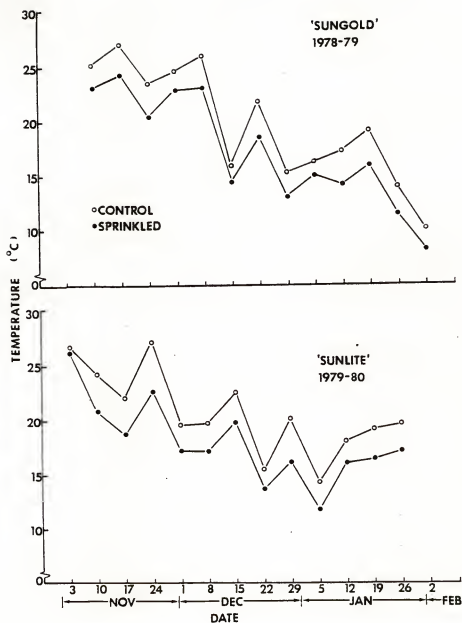


Fig. 5. Average weekly scaffold temperatures of control and sprinkled 'Sungold' and 'Sunlite' nectarine trees.

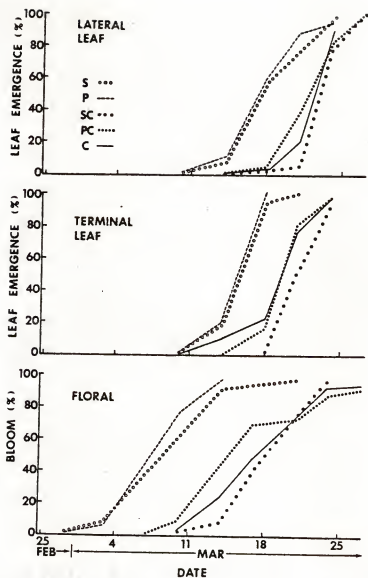


Fig. 6. Floral and vegetative bud-break on 'Sungold' nectarine trees, 1978-79. (S=sprinkled, P=sprinkled with plastic and mulch, SC=soaker hoses, PC=nonsprinkled with plastic and mulch, and C=control.)

This difference was also observed on budsticks forced in the greenhouse, although fewer days were required for bud-break and less difference was noted between treatments as budsticks were cut progressively later (Table 11). Budsticks from sprinkled treatments reached terminal and lateral leaf emergence 3 to 7 and 4 to 6 days earlier, respectively, than controls in 1978-79. There was a 5- to 11-day difference in 1979-80, depending upon the date when budsticks were cut. Terminal vegetative buds appeared less affected by sprinkling than lateral buds, probably due to differences in chilling requirements (47).

Sprinkled 'Sungold' trees reached 50% bloom approximately 11 to 12 days earlier than control trees in 1978-79 (Fig. 6). There was no difference in bloom of sprinkled trees (S) and sprinkled trees with plastic and mulch (P). Water applied to the canopy was apparently responsible for the advance in bloom, since water applied to the roots only (SC) resulted in bloom similar to that of control trees. Floral bud-break on budsticks cut from sprinkled trees was reached 3 to 8 days earlier than those from control trees in both seasons, with the smallest difference occurring on the last cutting date (Table 11). Walker and Seeley (100) postulated that a plant has completed rest if bud-break occurs within 14 days on a forced budstick. 'Sungold' trees sprinkled in 1978-79 completed rest on February 6, approximately 1 week prior to control trees. Forcing data for 'Sunlite' trees in 1979-80 indicated a 10-day bloom advance for sprinkled

Table 11. Days to floral and vegetative bud-break on greenhouse forced budsticks of 'Sungold' and 'Sunlite' nectarine.

Treatment <sup>2</sup>	Days to bud-break									
	'Sungold' 1978-79					late cut:				
	Jun 30	Feb 6	Feb 13	Feb 20	Feb 27	Jan 14	Jan 21	Jan 28	Feb 4	Feb 11
S	20.0	13.0	8.0	5.0	0	-- <sup>W</sup>	16.0	14.0	8.0	1.0
P	20.0	13.0	8.0	5.0	0	--	17.0	11.0	8.0	2.0
SC	38.5	20.5	14.0	12.0	7.0	--	21.0	17.0	17.0	8.0
PC	28.0	19.0	12.0	8.5	4.0	--	28.0	21.0	21.0	9.0
C	28.0	19.0	13.5	8.5	4.0	--	24.0	23.0	16.0	8.0
Floral <sup>Y</sup>										
Terminal vegetative <sup>X</sup>										
S	33.0	24.0	21.0	14.0	7.0	9.0	5.0	2.0	2.0	0
P	40.0	24.5	19.0	14.0	7.0	13.0	6.0	3.0	2.0	0
SC	42.0	31.5	24.0	19.0	14.0	15.0	8.0	7.0	8.0	7.0
PC	35.0	28.0	21.0	14.0	12.0	12.0	9.0	7.0	8.0	7.0
C	38.5	31.5	24.5	15.5	10.0	14.0	9.0	7.0	5.0	4.0
Lateral vegetative <sup>X</sup>										
S	35.0	24.0	21.0	17.0	12.0	10.0	10.0	8.0	7.0	4.0
P	35.0	22.5	20.5	15.5	12.0	14.0	9.0	8.0	5.0	7.0
SC	43.5	31.0	31.0	21.0	17.0	18.0	17.0	16.0	10.0	10.0
PC	38.0	31.0	28.0	24.0	19.0	22.0	20.0	16.0	14.0	10.0
C	45.0	28.0	30.5	24.5	12.0	21.0	14.0	14.0	16.0	9.0

<sup>Z</sup>S=sprinkled, P=sprinkled with plastic and mulch, SC=soaker hoses, PC=non-sprinkled with plastic and mulch, and C=control.

<sup>Y</sup>Bud-break defined as 5% bloom.

<sup>X</sup>Bud-break defined as leaf emergence.

<sup>W</sup>Data not available.

trees which completed rest on January 26. Fruit set was significantly decreased with a resultant increase in individual fruit weight on sprinkled trees (S and P) as compared to control trees (Table 12). This thinning effect has been observed in previous studies (19, 52) and is probably a result of dormant bud abscission due to increased wetting of the tree.

Differences in chill unit accumulation between sprinkled and nonsprinkled treatments, when summed as hours  $\leq 7.2^{\circ}\text{C}$ , hours  $\leq 10.0^{\circ}\text{C}$  and with the Utah model (79), were not sufficient to account for differences in bloom dates obtained. Temperature data were then converted to chill units using a model developed for low chilling nectarines (see Chapter I). The predicted date of rest completion was within 2 to 3 days of the actual date in 1978-79 and 5 to 7 days in 1979-80 for the nonsprinkled treatment (Table 13). The prediction was not accurate for sprinkled treatments, indicating the bloom response cannot be attributed solely to differences in scaffold temperature between treatments resulting from evaporative cooling.

Water application was approximately 0.39 and 0.30 cm-ha/day on sprinkled and soaker hose treatments, respectively, in 1978-79, compared to 0.16 and 0.12 cm-ha/day in 1979-80. The amount of water applied and the frequency of wetting may cause leaching of certain water-soluble substances, thus influencing bloom as suggested by Westwood and Bjornstad (112). Since carbohydrates are probably one of the most easily leached substances from plants (95), changes in levels of soluble

Table 12. Fruit set and fruit weight at thinning for 'Sungold' nectarine, 1978-79.

Treatment	Fruit per 2 m. limb <sup>z</sup> (no.)	Fruit weight (g) <sup>y</sup>
S	20.33a <sup>x</sup>	10.19b
P	25.67ab	12.87a
SC	34.75c	6.42d
PC	33.25bc	8.08c
C	40.33c	7.30cd

<sup>z</sup>Mean of 12 fruit-bearing limbs per treatment.

<sup>y</sup>Mean of 30 fruit per treatment.

<sup>x</sup>Mean separation within columns by Duncan's multiple range test, 5% level.

Table 13. Actual and predicted dates of rest termination of 'Sungold' and 'Sunlite' nectarine.

Computation method	Rest termination date									
	'Sungold', 1978-79					'Sunlite', 1979-80				
	Treatment					Treatment				
	S	P	SC	PC	C	S	P	SC	PC	C
Orchard forcing data <sup>z</sup>	36 <sup>y</sup> (Feb 5)	37 (Feb 6)	44 (Feb 13)	42 (Feb 12)	43 (Feb 12)	25 (Jan 25)	25 (Jan 25)	38 (Feb 1)	39 (Feb 8)	36 (Feb 5)
Low chilling model	29 (Jan 29)	30 (Jan 30)	41 (Feb 10)	41 (Feb 10)	41 (Feb 10)	7 (Jan 7)	6 (Jan 6)	31 (Jan 31)	32 (Feb 1)	31 (Jan 31)

<sup>z</sup> Based on bud-break within 14 days under forcing conditions.

<sup>y</sup> Julian date.



carbohydrates should give some indication of leaching. An increase in soluble carbohydrates in flower buds was evident from November 27 through February 26 in 1978-79 (Fig. 7). Studies have shown that sugars increase during winter, with a corresponding decrease in starch (38, 43), reaching a peak just prior to bloom (43). There were no significant differences among treatments in 1978-79. Sampling was initiated earlier in 1979-80, on November 5, before leaf abscission was complete. The high level of soluble sugars on this date indicated active growth had not yet ceased and solutes were probably being translocated out of the leaves. Soluble carbohydrates were at a minimum on December 10, after which they increased as in the previous season. The 2 sprinkled treatments showed the fastest increase with significantly higher levels the last 2 sampling dates. Forcing data indicated sprinkled trees had completed rest by January 28 (Table 11), thus, the significant increase in carbohydrates on January 28 may be a response to the cumulative cooling effect of water, resulting in earlier rest termination and an earlier resumption in growth with a resultant increase in translocation of carbohydrates. The increase was greatest February 26, due to increased activity prior to bloom. Increase in soluble carbohydrates in sprinkled treatments was not significantly greater than other treatments in 1978-79. Amount of water applied was over twice as great, thus, it is possible that leaching was occurring and was masking any increase due to early growth. Dowler and King (38) reported a

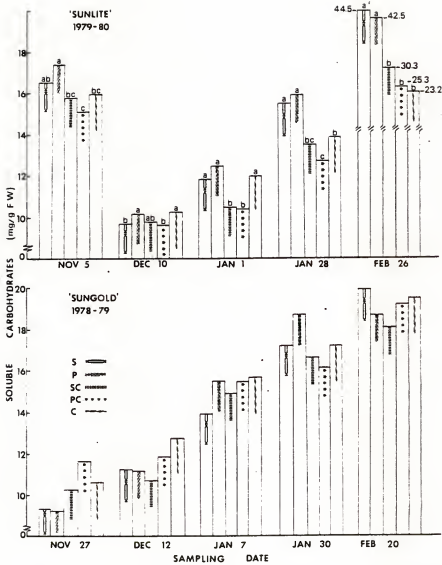


Fig. 7. Soluble carbohydrate content of 'Sunlite' and 'Sungold' nectarine flower buds. (Mean separation within sampling dates by Duncan's multiple range test, 5% level).

significant negative correlation between temperature and sugar content in peach scaffold wood, with sugar content increasing as average maximum temperature decreased. This effect may have contributed to present results, since maximum temperatures were lowered as much as  $4.3^{\circ}$  C. Determining the exact date a plant begins responding to chilling temperatures is a recurrent problem in rest and dormancy studies. If minimum soluble carbohydrate levels could be correlated with other factors such as leaf fall and temperature, they might be useful in pinpointing when low temperatures become effective in satisfying the chilling requirement.

If the increase in soluble sugars in sprinkled treatments was related to differences in root temperature, this should have been evidenced by differences in soil temperature, an indirect measure of root temperature. The largest diurnal soil temperature fluctuations were in treatments S (sprinkled) and SC (soaker hoses) (Fig. 8). This would be expected due to increased thermal conductivity as a result of increased soil moisture. The same degree of fluctuation was not noted in other treatments; thus, the similarity in bloom response of the S and P treatments is probably not due to soil temperature effects.

Westwood and Bjornstad (112) hypothesized leaching of a water-soluble substance such as abscisic acid (ABA) to explain the reduction in time required to break rest of apples and pears. Differences in bloom dates between sprinkled and non-sprinkled trees in the present study may have resulted from

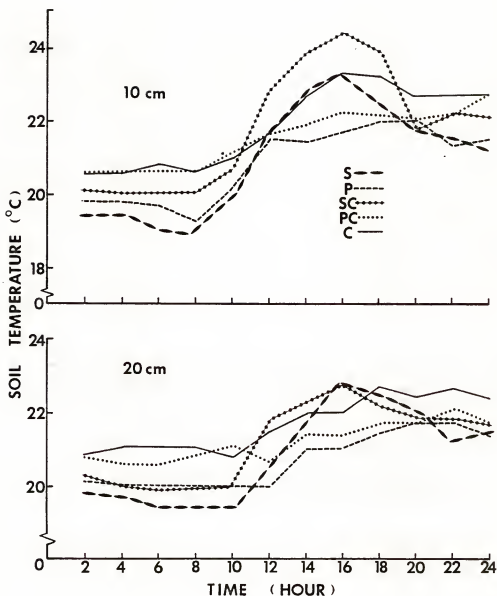


Fig. 8. Hourly soil temperatures at 10 and 20 cm under 'Sungold' nectarine trees, December 31, 1978. (S= sprinkled, P=sprinkled with plastic and mulch, SC=soaker hoses, PC=nonsprinkled with plastic and mulch, C=control.)

leaching of ABA, thus confounding the results where differences could be attributed to temperature reductions. This effect would be most likely in the 1978-79 season when water application was twice as great as in 1979-80.

There were no significant differences in mineral element content among treatments which could be attributed to leaching (Tables 14 and 15). These results agree with those of Bauer et al. (8). There were significant increases in both Ca and Mg for sprinkled treatments due to high concentrations of these ions in the irrigation water. Heavy deposits on the branches resulted in a white surface residue which may have increased the cooling effect by light reflection.

Evaporative cooling is effective in advancing the date of rest termination of low chilling nectarines. The chill unit model failed to predict rest completion of sprinkled treatments, suggesting other factors are involved in addition to temperature. Leaching may be influencing bloom when a high rate of water is applied by overhead sprinkling.

Table 14. Mineral element content of 'Sunlite' nectarine dormant buds, 1979-80.

Treatment <sup>z</sup>	Sampling date				
	Nov 6	Dec 4	Jan 4	Jan 29	Feb 26
	Ca (% dry wt.)				
S	.91ab <sup>y</sup>	1.29	1.65a	1.80a	3.70a
P	.92ab	1.05	1.60a	1.73a	2.88b
SC	1.10a	.91	.94b	1.00b	2.95ab
PC	.89b	.83	.91b	.96b	3.71a
C	.92ab	1.19	.98b	.94b	3.35ab
	Mg (% dry wt.)				
S	.12b	.22a	.25a	.24a	.14
P	.13ab	.22a	.23a	.24a	.13
SC	.15a	.13b	.14b	.15b	.12
PC	.12b	.13b	.13b	.15b	.14
C	.13ab	.12b	.13b	.14b	.12
	P (% dry wt.)				
S	.12	.16	.18a	.22ab	.39a
P	.14	.14	.17ab	.24a	.42ab
SC	.16	.16	.17ab	.23ab	.42ab
PC	.12	.16	.16ab	.24a	.47b
C	.12	.13	.14b	.19b	.43ab
	K (% dry wt.)				
S	.19a	-- <sup>x</sup>	.19a	.16	1.55a
P	.21a	--	.13b	.20	1.38ab
SC	.26b	--	.13b	.20	1.23ab
PC	.21a	--	.09c	.18	1.30b
C	.20a	--	.20a	.23	1.11b
	Mn (ppm)				
S	8.0bc	9.1ab	8.5ab	12.8ab	16.3a
P	10.7ab	11.0a	11.1bc	16.3a	20.8b
SC	12.5a	11.3a	11.1bc	15.8a	17.9ab
PC	7.4c	7.9b	7.3a	11.5b	16.8ab
C	10.8ab	10.3ab	12.3c	14.6ab	20.1ab

<sup>z</sup>S=sprinkled, P=sprinkled with plastic and mulch, SC=soaker hoses, PC=nonsprinkled with plastic and mulch, and C=control.

<sup>y</sup>Mean separation within columns by mineral elements by Duncan's multiple range test, 5% level.

<sup>x</sup>Data not available.

Table 15. Mineral element content of 'Sunlite' nectarine dormant wood, 1979-80.

Treatment <sup>z</sup>	Sampling date				
	Nov 6	Dec 4	Jan 4	Jan 29	Feb 26
Ca (% dry wt.)					
S	1.30a <sup>y</sup>	1.56a	1.76a	1.89a	1.56a
P	1.09b	1.05b	1.28b	1.41b	1.04b
SC	1.32a	1.28b	1.28b	1.76a	1.20b
PC	1.35a	1.16b	1.38b	1.72a	1.23a
C	.90b	1.09b	1.17b	1.17b	.99b
Mg (% dry wt.)					
S	.09	.11a	.13a	.14a	.10
P	.10	.10a	.13a	.14a	.10
SC	.10	.08b	.09b	.11b	.09
PC	.10	.08b	.09b	.10bc	.08
C	.08	.08b	.09b	.10c	.08
P (% dry wt.)					
S	.17bc	.16ab	.18	.19bc	.17ab
P	.17bc	.14a	.17	.18c	.14a
SC	.20a	.18b	.18	.21ab	.18c
PC	.18ab	.17b	.19	.21a	.18c
C	.15c	.17ab	.18	.17c	.16ab
K (% dry wt.)					
S	.36	-- <sup>x</sup>	.32	.47a	.39a
P	.41	--	.33	.35b	.40a
SC	.40	--	.33	.39ab	.51b
PC	.41	--	.30	.40ab	.38a
C	.39	--	.35	.43ab	.40a
Mn (ppm)					
S	100.0ab	101.3bc	110.6ab	129.4ab	126.3ab
P	120.6ab	90.0bc	123.8a	136.9ab	133.8a
SC	125.0a	81.3bc	126.9a	146.9a	136.3a
PC	95.0b	58.1a	92.3b	108.8b	96.9b
C	108.8ab	105.0c	125.6a	126.3ab	121.8ab

<sup>z</sup>S=sprinkled, P=sprinkled with plastic and mulch, SC=soaker hoses, PC=nonsprinkled with plastic and mulch, and C=control.

<sup>y</sup>Mean separation within columns by mineral elements by Duncan's multiple range test, 5% level.

<sup>x</sup>Data not available.

## CHAPTER IV

### TEMPERATURE CHAMBER EQUIPMENT AND CONTROL

Controlled environment facilities are usually expensive for both construction and maintenance (34). Utilization of such facilities is often cost prohibitive, especially for research projects requiring several temperature conditions simultaneously. A system of controlled chambers including such features as accurate temperature regulation over a wide range, versatility of use and low cost would expand the capabilities of many plant researchers.

The system described here was designed to serve as controlled temperature chambers to be used in chilling and dormancy studies. A flow chart of major system components is presented (Fig. 9). A Commodore Pet 2001 Series Microprocessor was used as the monitor and control device for eight  $4.6 \text{ m}^3$  chest type freezers. Five chambers were maintained at constant temperatures of  $0.6^\circ$ ,  $3.3^\circ$ ,  $7.0^\circ$ ,  $10.0^\circ$  and  $15.^\circ\text{C}$  for the present experiment. Three additional chambers were used for diurnally fluctuating day/night regimes of  $7^\circ/0^\circ$ ,  $15^\circ/7^\circ$  and  $30^\circ/7^\circ \text{ C}$ . Incandescent light bulbs of 40, 75 and 200 watts, respectively, were used as heat sources to maintain maximum temperatures in diurnal chambers.



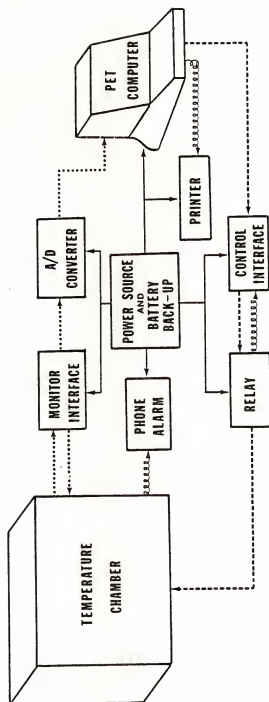


Fig. 9. Flow diagram for temperature chamber control system.

The temperature in each chamber was sensed by 2 solid state temperature transducers placed in opposite ends of the chamber at plant height. A small circulating fan was mounted inside each chamber to help maintain uniform temperature throughout the chamber. Hourly temperatures were recorded on a Commodore 2022 Series printer.

Chamber temperatures were sensed via the monitor interface and A/D converter at approximately 3 to 4 sec intervals for a total of 50 readings which were then averaged. The resulting temperature was then compared to the desired one for that chamber. The microprocessor then turned on the freezer compressor via the control interface and relay if the temperature was above the range specified in the computer program. The microprocessor continued monitoring each chamber temperature sequentially. (One loop through all 8 chambers was thus completed in approximately 24 sec.) Each compressor was turned off when the minimum temperature for the chamber was reached.

Due to a high incidence of power fluctuations, a battery back-up system was installed to prevent microprocessor failure and subsequent loss of chamber control. Power was supplied to the system by a power inverter which was in turn powered by a 12v power supply. In the event of a power failure, control was automatically switched so that power was supplied by two 12v marine batteries with simultaneous activation of a phone alarm system.

This system has been used successfully for rest and chilling studies. Incandescent and/or fluorescent lights may be installed for growth studies. The temperature range ( $-20.0^{\circ}$  C to  $40.0^{\circ}$  C) enables the system to be used for freezing studies. The researcher has several options available and should be able to modify the system to meet specific research needs.

## CONCLUSIONS

Controlled temperature chamber studies with 1-year-old 'Sungold' nectarine plants indicate there are cultivar dependent differences in chilling temperature effectiveness. Chilling at 10° C was as effective as 7° C for floral bud-break. After an initial rapid response, bud-break was slowed but not nullified by a high temperature interruption in the middle of the chilling period; however, a high temperature of 30° C alternated with 7° C in a daily cycle did nullify chilling. Frequent periods of high temperature following short periods of chilling are thus more antagonistic to chilling than occasional longer periods of high temperature. Exposure to diurnally fluctuating temperature regimes generally resulted in bud-break intermediate to that of the 2 constituent temperatures given as continuous chilling treatments. Days to bud-break significantly decreased as chilling increased up to 750 hours, but the decrease was progressively less with each 100 hour increment above the assumed chilling requirement; thus, the rate of bud-break of field-grown plants probably increases even at supraoptimal chilling levels, rather than reaching a plateau once the chilling requirement has been satisfied. Temperature influenced floral buds more than vegetative buds both under continuous and interrupted treatments. Emphasis

should, therefore, be placed on floral buds when determining chilling requirements or developing prediction models.

The rest prediction model developed from combined floral bud-break data for low chilling cultivars is broader with a higher optimum chilling temperature than models developed for cultivars with higher chilling requirements (79). The shift in optimum temperature from 6° to 8° C and the divergence between 8° and 18° C probably contribute to the failure of previous models to predict rest termination accurately in mild climates where winter temperatures often fall within this range.

A similar experiment with dormant rabbiteye blueberry budsticks indicated cultivar differences exist in both chilling requirements and chilling temperature effectiveness. 'Tifblue' floral buds did not respond to 15° C as fast as 'Woodard' and 'Bluegem', both as a continuous treatment and in a diurnal cycle with 7° C. This narrower range of effective chilling temperatures for 'Tifblue' suggests 'Woodard' and 'Bluegem' are better adapted to mild climatic conditions due to a wider chilling temperature range. Slight differences in response to chilling temperatures were also evident between 'Woodard' and 'Bluegem', probably due to differences in chilling requirement or method of growing-degree-hour accumulation. Chilling temperature influence was greater on 1-year-old 'Woodard' rooted cuttings than budsticks. This may affect extrapolation of budstick chilling data to mature plantings.

Evaporative cooling of 'Sungold' and 'Sunlite' nectarine trees advanced bloom 11 days compared to control trees. Water applied to the canopy and not the roots was apparently responsible for the bloom advance, since water applied only to the roots, by means of soaker hoses, resulted in response similar to control trees. The low chilling model developed for 'Sungold' predicted rest termination accurately only for nonsprinkled treatments, suggesting other factors are involved in addition to temperature. Comparison of diurnal soil temperature fluctuations between sprinkled trees and sprinkled trees with plastic and mulch indicates similarity in bloom is not due to soil temperature differences resulting from soil moisture differences. Soluble carbohydrate analysis suggests leaching may be involved when a high rate of water is applied by overhead sprinkling.

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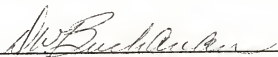


## BIOGRAPHICAL SKETCH

Phyllis Robinson Gilreath was born on November 5, 1952, in Greeneville, Tennessee. She was raised and received her primary and secondary education in Knoxville, Tennessee. In June 1974, she was awarded the degree of Bachelor of Science in Agriculture in the Department of Ornamental Horticulture and Landscape Design at the University of Tennessee. In May 1976, she received the degree of Master of Science from Clemson University with a major in horticulture. She entered the University of Florida in June 1976, and was awarded the degree of Doctor of Philosophy in December, 1980, with a major in Horticultural Science (Fruit Crops).

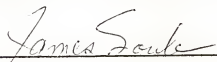
She married James Preston Gilreath of Greenville, South Carolina, on June 21, 1975.

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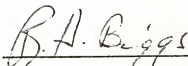


Dr. D. W. Buchanan, Chairman  
Professor of Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


  
James Soule  
Professor of Horticultural Science

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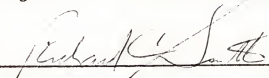
R. H. Biggs  
Professor of Horticultural Science

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F. S. Davies  
Assistant Professor of  
Horticultural Science

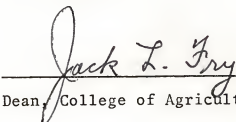
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R. C. Smith  
Professor of Botany

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1980

  
Dean, College of Agriculture

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Dean, Graduate Studies and Research